Human Performance Assessments
when Using Augmented Reality for Navigation

Brian F. Goldiez, Ph.D., Nabin Saptoka, Prashanth Aedunuthula
Institute for Simulation and Training
3100 Technology Parkway
Orlando, Fl 32820
USA

OVERVIEW

Human performance executing search and rescue type of navigation is one area that can benefit from augmented reality technology when the proper computer generated information is added to a real scene. Search and rescue is characterized by the need to completely inspect a space, find an objective, and exit the space. Time is of the essence in completing this type of task and the environment is normally not familiar to the user, and lacks known landmarks. We briefly report on an experiment that demonstrated the benefits of augmented reality in a search and rescue task. Specifically, 120 participants, equally divided by gender, were tested in speed and accuracy using augmented reality in a search and rescue task. Accuracy performance was improved using augmented reality as compared to the control conditions. Additionally, a user controlled On-Demand display resulted in better performance than a Continuously On display.

We report on additional analysis performed on data gathered during the augmented reality experiment. Specifically the data involves whether the sense of presence occurred during the task, how one can measure presence in augmented reality environments, and the extent to which individual differences were factors in performance. While presence was not found in the experiments, new insights and measurement approaches emerged. Individual differences also exhibited some interesting results. Spatial recall and ingress-egress time were the independent variables measured against various factors obtained from demographics. Briefly, when individual treatments are aggregated, individuals between 25-35 years of age took longer to traverse the maze when compared to both older and younger groups. Likewise, females and persons with spatially oriented academic majors took longer to traverse the maze. We conjecture that these increases in times are due to well known gender differences, maturity or existing training in spatially oriented tasks.

BACKGROUND

In augmented reality, "a participant wears a see-through display (or views video of the real world with opaque HMD) that allows graphics to be projected in the real world" (Barfield & Caudell, 2001, pg. 6). It holds great promise to enhance human performance in the real world by providing contextually relevant information to the user on demand. Unlike virtual reality (VR), where the user is immersed solely in a computer generated environment, augmented reality allows the user to see the real world with computer generated images superimposed. Milgram, Takemura, Utsumi, and Kishino (1994) use the terms reproduction fidelity, extent of presence, and extent of world knowledge augmented to describe the functional characteristics of virtual and augmented reality systems. These terms represent respectively i) the graphics quality, ii) the degree to which

Report Documentation Page		*Form Approved* *OMB No. 0704-0188*

Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.

1. REPORT DATE **01 JUN 2006**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**

4. TITLE AND SUBTITLE **Human Performance Assessments when Using Augmented Reality for Navigation**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Institute for Simulation and Training 3100 Technology Parkway Orlando, Fl 32820 USA**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADM002024., The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**UU**	**31**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

the user forms an integrated mental model, and iii) the amount of real world knowledge available via the computer.

Because the type of computer generated information in augmented reality is only generally described, it is useful to further categorize the computer generated information into three classes; information that is intended to be fused and indistinguishable from the real world, information that is not visible without augmentation (e.g., sensor information fused to a background), and information that is not part of the environment but retains the characteristics of augmented reality systems, such as a head up display. This classification scheme is useful for two reasons. First, certain types of augmented reality technology are just now reaching a state of maturity where some human performance studies may be conducted. Secondly, we believe that certain tasks may be amenable to particular augmented reality technical approaches allowing testing to be conducted sooner supporting development of design and usage guidelines. Further, closely linking research related assessments and development can accelerate augmented reality's maturation and introduction into society.

Additional uses of augmented reality are being suggested as the technology matures (see Azuma, 1997 and 2001). The literature suggests functional groupings of augmented reality uses in manipulative tasks, decision aides, and navigation. A more contemporary form of augmented reality related to annotations and visualizations are finding their way into modern media with computer generated advertisements added to a real world sporting event background. In military aircraft head up displays and helmet mounted sights are also examples of augmentation.

One area of human performance that is just beginning to be studied in augmented reality is navigation or wayfinding. Wayfinding is characterized by acquiring landmark, route, and survey knowledge about an area as described by Siegel and White (1975). Wayfinding is one of the crucial application areas for augmented reality in areas such as public safety. This paper explores a particular type of navigation we term search and rescue. Search and rescue navigation is characterized by the requirement to quickly cover an entire space searching for an object, finding that object, and exiting with it as quickly as possible. Shortness of time, retrieval of the object, and full exploration of the space are required.

Wearable computer technology makes real-world wayfinding studies feasible. Augmented reality which employs wearable computers offers the possibility for training that overcomes limitations often experienced in virtual reality systems, such as restrictions in self motion that can result in simulator sickness. Additionally, virtual reality systems require dedicated and specialized spaces as well as consume a relatively large footprint. However, critical technology developments remain in several areas of augmented reality including tracking, displays, human factors, and power. For example, Azuma, et al. (2001) discuss persistent problems with displays such as the dynamic range of brightness, limited field of view, and fixed contrast ratio that restrict the blending of real and synthetic images. However, displays for gaming are making advances across some of these areas while keeping the cost per unit reasonable for consumers. Likewise, support for occlusion in optical displays has been prototyped by including special LCD panels in the optical path. Display sizes for augmented displays are also decreasing with eyeglass type of displays becoming available. Progress is being made across a broad front of technology.

EXPERIMENTAL DESIGN

The experiments described herein used a mobile augmented reality system. This system, called the Battlefield Augmented Reality System (BARS), was integrated and configured by the Naval Research Laboratory for experimentation and provided for this research by the United States Army Research Institute for Behavioral

Sciences. Images of the system can be seen in Figure 1. For this experiment, the BARS was configured as an augmented reality system which uses information that is not part of the environment but retains the characteristics of augmented reality systems. The BARS uses a Thermite computer from Quantum 3D as the central processing unit. The Thermite is a battery operated wearable computer. It uses a 1 G Hz Transmeta central processor, with supporting hardware from NVDIA GeForceFX Go GPU for graphics processing. The configuration of the Thermite for this research used the Windows operating system and provided several options for display outputs (VGA is used in BARS). Visuals are provided to the user with a MicroOptical SV-6 PC Viewer. The SV-6 has 640 pixels by 480 lines resolution, 18 bit color depth (262,144 colors), an approximate 16 degree x 20 degree field of view, 60 Hertz refresh, and adjustable focus from 2 to 15 feet. The setting of focus helps facilitate placing images at pre-selected distances to facilitate depth perception. The maze used to conduct the simulated search and rescue task is shown in Figure 2.

Figure 1: Front and Side View of the Battlefield Augmented Reality System (BARS).

Entrance

Figure 2: Oblique Photograph of the Maze.

One hundred thirty six participants, eight of which were used in a pre-testing pilot study, were employed in the study. Seven of the 136 participants were not used for procedural reasons and one for equipment failure during the experiment. This left a total of one hundred twenty participants in the final sample with mean age of 26.5 years and standard deviation of 9.9 years. Participants were divided equally between the treatment conditions which were also balanced for gender.

There were two tasks that each individual participant had to accomplish. The primary task was to completely traverse the maze including dead ends before retrieving the target object and then immediately find the shortest way back to the entrance. The secondary embedded task was to answer spatially oriented questions placed at five different stations in the maze. The primary purpose of the secondary task was to test spatial orientation but a secondary purpose was to mitigate the occurrence of a ceiling effect by imposing an additional requirement on participant's working memory. Spatial recall of the maze layout and object location was also required.

Six conditions were evaluated. Two control conditions were employed without augmentation. In one, time started when the participant was given a paper map to review at the entrance of the maze (figure 2). The map was retrieved when the participant began traversing the maze. In the second control condition the participant was not given a map, but did have the use of a compass as they traversed the maze. Two variables were crossed yielding the additional four experimental conditions. The two variables were a continuously on map display versus a user controlled map (so-called On Demand display) and a fixed north up map (exocentric) versus a forward up (egocentric) map display. No maps or compasses were provided to participants using augmented reality in the experimental treatments.

Prior to the experiment, participants completed an informed consent and demographic questionnaire. Parts 5 and 6 of the Guilford-Zimmerman (G-Z) Aptitude Survey were administered for spatial abilities (Consulting Psychologists Press, 1976). Participants were also asked to answer the Immersive Tendencies Questionnaire

that was adapted for AR. After traversing the maze participants were given the Presence Questionnaire adapted for AR and a spatial recall test (see Goldiez, 2004).

RESULTS

Data collected from each participant consisted of the time taken to traverse the maze, the percent of the maze covered, estimations of Euclidian distance and direction, estimations of Cardinal direction, and spatial recall of the maze layout and location of the object. A variety of pre and post hoc questionnaires were also administered covering demographics, spatial abilities, and presence.

The results from the experiment suggest that a higher level of accuracy is achieved using augmented reality. Less time was needed to traverse the area without augmentation, but we conjecture that this was due in part to the small size of the maze. As one might expect from the literature, augmented reality systems employing egocentric displays result in better performance for making estimations of Euclidian distance and direction while exocentric displays result in better estimation of Cardinal direction. On Demand displays generally result in improved performance compared to continuously on displays. See Goldiez (2004) for complete results.

Additional data were analyzed regarding the occurrence of presence and the impact of demographics on performance. Presence is generally defined as 'the sense of being somewhere other than your physical location'. It is a psychological phenomenon that is mediated by media (in the present context by the augmented reality equipment), task, and predisposition of the participant. No direct impact of presence was detected using adapted versions of the Witmer-Singer Immersive Tendency and Presence Questionnaires (Goldiez, 2004) and the analysis methods suggested by Witmer and Singer (1998). Demographic information gathered from participants was analyzed with respect to its impact on performance. Demographic data showed no impact on performance when individual treatments were analyzed except for the well documented effect of males performing better than females in spatially oriented tasks were extended to this experimental domain.

Further investigation into the data revealed some interesting affects with respect to presence and demographics. For example, a question added to the Witmer-Singer Immersive Tendency Questionnaire asked participants to what extent they rotate maps when reading them. Those indicating that they tended not to rotate maps exhibited better performance with respect to traversal time than those indicting that they tend to rotate maps when reading them. The difference in traversal times between these groups was in excess of 100 seconds when nominal traversal times were on the order of 400 seconds ($p \leq 0.030$). It is important to emphasize that this question was posed before the experiment and it is not known whether the individual actually rotates the map during a navigational task. We infer from this finding that individuals who build fixed map mental models do better in navigation than those who do not build such models.

Further investigation of the presence questionnaires was conducted. The initial approach to analyzing presence was to select three questions each from the adapted Immersive Tendency and Presence Questionnaires and investigate the degree of statistical correlation. The correlation was poor. Subsequently, we evaluated the reliability scale of individual questionnaires using the clustering suggested in Witmer and Singer (1998), but with our adapted questionnaire which eliminated and added selected questions (see Goldiez, 2004). Reliability as expressed by Cronbach's alpha was still below the .7 value considered to good (Pallant, 2001).

A complete exploratory factor analysis was subsequently conducted on the adapted versions of the Immersive Tendency and Presence Questionnaires. A completely different clustering of questions resulted. The original work by Witmer and Singer clustered Immersive Tendency questions using the terms Focus, Involvement, and Games. The value of Cronbach's Alpha for each factor was below 0.7 for the experiment described herein. The new clustering organizes questions into what we term Psychomotor Tendencies, Cognitive Involvement, and Perceptual Involvement. The regrouping of the questions under these latter categories has Cronbach Alpha values all above 0.7. In the case of the adapted Presence Questionnaire, the original work of Witmer and Singer clustered factors into two categories; Involvement/Control and Interface Quality. A category called New Gear was added to reflect the wearable augmented reality equipment used in this experiment reflecting wearable computing equipment. Reliability scales using Cronbach's Alpha were all less than 0.7. New factors that emerged we term Human Computer Interface Factors, Technical Factors, and Kinesthetic/Tactile exploratory factor analysis. On an aggregate basis, each of the new Presence Questionnaire factors showed improvement compared to the original factors although two factors remain slightly below the 0.7 threshold.

Demographics were also further analyzed with respect to the impact of specific demographic attributes on performance. As previously stated, when individual treatments were considered the only demographic information that impacted performance when using augmented reality in the experimental task was sex. A different approach was taken to further analyze demographic data. Ingress-Egress Time and spatial recall were the dependent variable aggregated across various combinations of control groups and experimental treatments. Spatial recall was scored as 50 points for selecting the correct maze and target object location, 10 points for selecting the correct maze or object, and 0 points for failing to select either. The demographic factors considered for further analysis were age, academic major, profession, and previous virtual reality experience. Academic major and profession were focused on those that might require spatial and/or quantitative abilities. Age was grouped into three categories; 25 years of age or younger, above 25 but less than or equal to 35, and above 35. The distribution of participants by age was 76, 28, and 16, respectively. Academic majors were classified into four categories; physical science, social sciences, humanities, and other. The distribution of participants among these four categories was 57, 24, 17, and 22, respectively. Profession was classified into three categories; spatial (e.g., engineer), non-spatial (e.g., English teacher), and other. The distribution among these three categories was 21, 20, and 79, respectively (many participants were students). 38 participants had some form of virtual reality experience.

In a few cases, the findings from the additional analysis of demographics showed some statistically significant findings. An ANOVA for traversal time across all treatments considering physical science majors compared to all other majors found that participants indicating a physical science major were statistically different (mean time 381 sec) from an aggregate of majors (mean time 306 sec) for the control group with a map ($F(1,18) = 4.22$, $p \leq 0.05$). Also a two-way ANOVA of traversal time versus spatial recall and age group revealed that their interaction is statistically significant ($F(4,111) = 5.34$, $p \leq 0.001$).

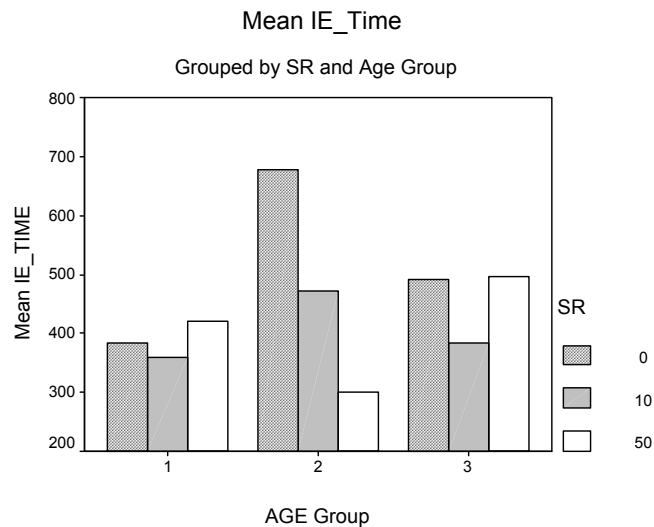Mean IE_Time

Grouped by SR and Age Group

Figure 3: Mean IE_Time across Age Group/SR.

In the bar plot (Figure 3, above) of the mean traversal time (ordinate), it can be observed on a qualitative basis, that the nature of the bars for SR=50 (plain bar) is just opposite than the two other bars for SR= 0 (cross hatched) and SR=10 (solid filled bar) for those aged 25 to 35. The variability in traversal for the age group '1' (under 25 years of age) is smaller than the other age groups. Age group '2' (age 25 to 35) has higher variability than that of age group '1'. It is also interesting for age group '2' that those who scored perfect score clocked less average time than those who were partially able to or completely unable to recall maze and the location of the object. It is quite natural to expect having an increase in recall accuracy with an increase of time spent inside the maze, however, group '2' contradicts with this general belief.

CONCLUSIONS

This study has shown that augmented reality can improve aspects of human performance in search and rescue type of navigation tasks. This study has also shown that more development needs to occur, particularly in the human factors and assessment aspects of the technology. Getting firmer grounding in these two areas will provide valuable insights into where high payoff technical development should occur.

With respect to human factors, anecdotal data collected points to the need for hands free operation when using an On Demand Display. Likewise, smaller latency between movement and display results as well as more stable display output would mitigate some orientation issues.

In the area of assessment, a larger maze is desirable to see where working memory becomes saturated and augmentation's value can be realized. Also, more questions that are applicable across media and tasks are needed to be added and vetted for questionnaires, especially with respect to the Presence Questionnaire.

Assessments specifically oriented to demographics needs to be conducted. However, some general conclusions can be drawn from the present work. People with a quantitative major or those in the middle age group (25 to 35 years of age) seem to be more deliberate and thoughtful in their use of augmented reality and generally took longer to traverse the maze. We believe that this is because these groups might be more inquisitive than the other groups. Also, physical science majors took longer to execute the primary and secondary tasks than other discipline categories in the control treatment with a map. Again, we believe this

effect might be due to an inquisitive nature of this type of individual and the use of new technology. Age also showed significance in the time to conduct the tasks, but in two unusual ways. First, age was only statistically significant for traversal time in the Exocentric Continuous Display treatment and only for age group 2 (ages 25-35) participants who exhibited significantly poorer performance than other age groups in this treatment. Within age group 2 (and disregarding treatment type) it was observed that those who had perfect spatial and object recall took less time to execute the primary and secondary tasks than those who were at best partially correct in SR. One might infer from this data that physical science majors, between the ages of 25-35 gain more by using augmented reality systems for search and rescue navigation because of the improved performance in traversal time and spatial recall compared to other groups, in particular a control condition (with map) where traversal time suffered. But we believe that what these results really indicate is the need for additional technical development, human factors work, and assessment.

The lack of demographic related findings across a broad range of augmented reality treatments leads one to conclude that further work in AR development is needed in combination with integrated studies involving increased task complexity and equipment utility so that issues affecting society's use of AR can be better ascertained.

REFERENCES

Azuma, R. T. (2001). Augmented reality: Approaches and technical challenges. In W. Barfield & T. Caudell (Eds.)*, Fundamentals of wearable computers & augmented reality* (pp. 27-63). Mahwah, NJ: Lawrence Erlbaum and Associates.

Azuma, R.T., Baillot, Y., Behringer, R., Feiner, S., Julier, S., & MacIntyre, B. (2001). Recent advances in augmented reality. *Computer Graphics & Applications*, *IEEE, 21* (6), 34-47.

Azuma, R. T. (1997). A survey of augmented reality. *Presence: Teleoperators & Virtual Environments, 6* (4), 355-385.

Consulting Psychological Press. (1976). Palo Alto, CA: Consulting Psychological Press.

W. Barfield, and T. Caudell (2001), "Basic concepts in wearable computers and augmented reality," *Fundamentals of wearable computers and augmented reality*. W. Barfield and T. Caudell, eds., Mahwah, NJ: Lawrence Erlbaum and Associates. pp. 3-26, 2001.

Goldiez, B. (2004). *Techniques for assessing and improving performance in navigation and wayfinding using mobile augmented reality*. Unpublished doctoral dissertation, University of Central Florida, Orlando.

Milgram, P., Takemura, H., Utsumi, A., & Kishino, F. (1994). Augmented reality: A class of displays on the reality-virtuality continuum. *Proceeding of Society for Photographic and Information Engineering, Telemanipulator and Telepresence Technologies, Vol. 2351*, unknown location, 282-292.

Pallant, J. (2001). SPSS Survival Manual: A step by step guide to data analysis using SPSS. Berkshire, UK: Open University Press.

Siegel, A. W., & White, S. H. (1975). The development of spatial representations of large-scale environments. In H. W. Reese (Ed.)*, Advances in child development and behavior* (pp. 9-55). New York, NY: Academic Press.

Witmer, B. G., & Singer, M. J. (1998). Measuring presence in virtual environments: A presence questionnaire. *Presence: Teleoperators & Virtual Environments, 7*, 225-240.

ACKNOWLEDGEMENT

HUMAN PERFORMANCE ASSESSMENTS WHEN USING AUGMENTED REALITY FOR NAVIGATION

Brian Goldiez, Nabin Saptoka, Prashanth Aedunuthula
Institute for Simulation & Training
University of Central Florida

June 2006

Outline

- Overview of AR
- Description of Navigation Experiments
- Results and Analysis of Experimental Data
- Additional Data Analysis Research
  - Presence
  - Demographics
- On-Going Research

Augmented Reality Overview

- Overlaid Computer Graphics onto a Real World Scene-Contemporary
  - Combines real and virtual
  - Interactive in real time
  - Registered in 3D
    (Azuma, 1997, Presence)
- Can Include Other Sensory Modalities
- Can Remove as Well as Add Content
- Anchoring Determines Virtual or Augmented Reality

Task \ AR Type	Added Content	Fused	Multi-Spectral
Self Motion			
Manipulation			
Cognition			

University of Central Florida

Example Technologies

Photos from Azuma, et. al, "Recent Advances in Augmented Reality Nov. 2001, Computers and Graphics
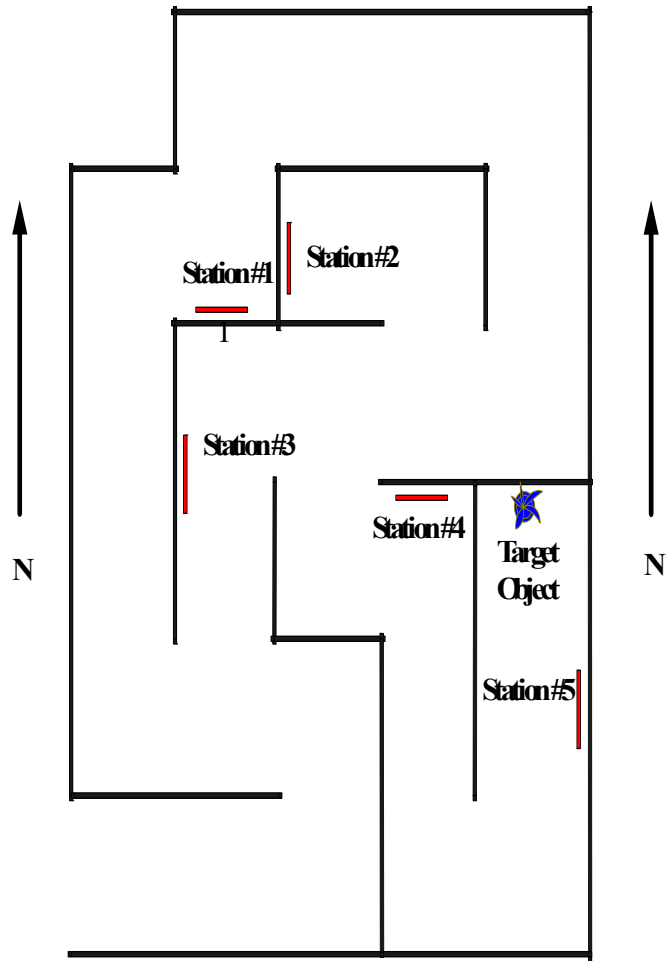
Sample AR Application

Navigation Research Using AR

AR Supporting Navigation

- Human Performance ⟷ Technology & Design Guidelines
- Search & Rescue Wayfinding
  - No Training Involved
  - Complete Exploration During Ingress
  - Expeditious Egress
- Traverse an Unfamiliar Area (e.g., Maze) to Retrieve an Object
- Keep Track of Relative and Absolute Spatial Orientation
  - Dual Task
  - Recall Accuracy
- Incentive for Performance
- Experimental Design (120 Participants)
  - 2x2 Between Subjects
  - 2 Control Conditions
  - Secondary Working Memory Task
  - Balanced for Gender

University of
**Central
Florida**

Mobile AR Apparatus UCF

Station#1
Station#2
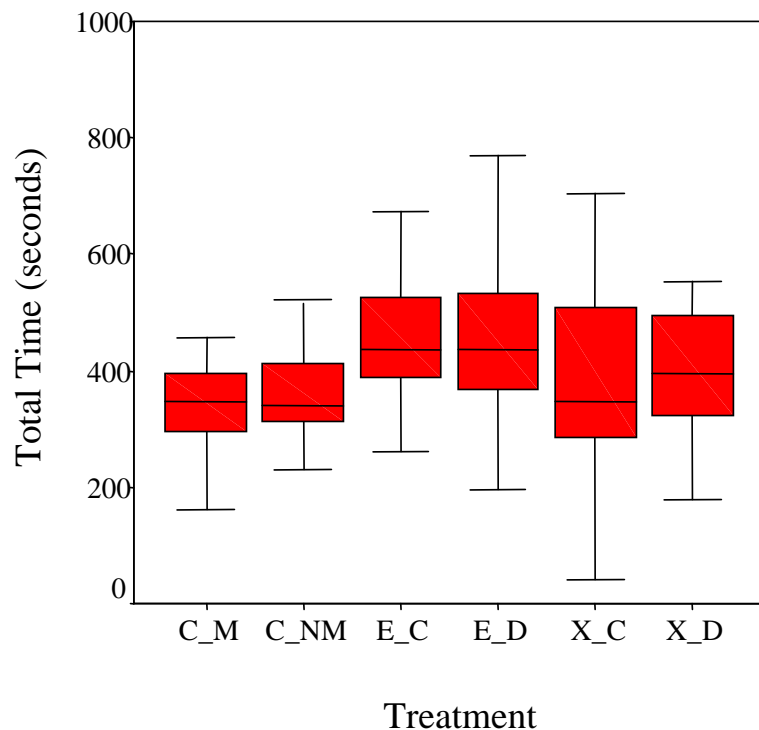Station#3
Station#4
Target Object
Station#5
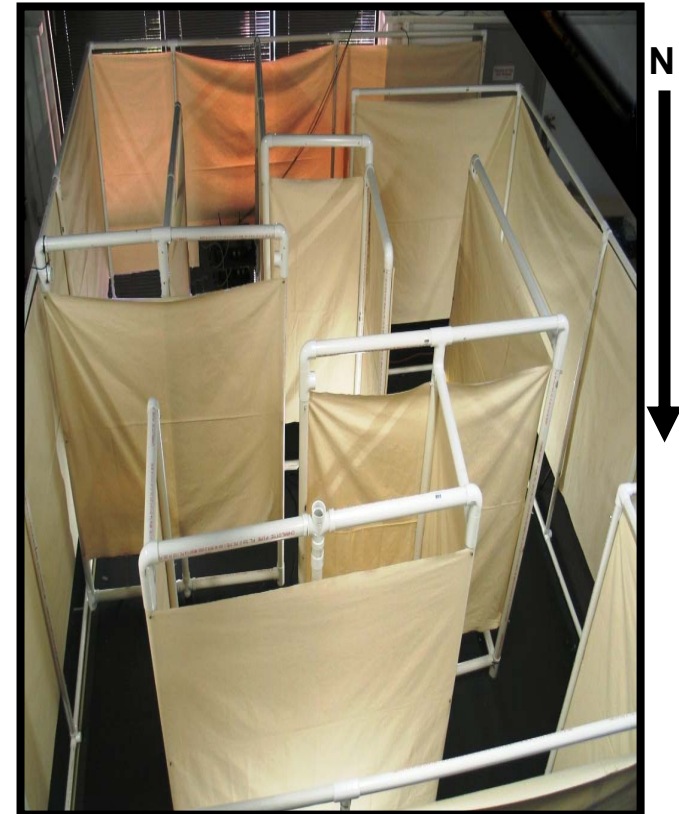
Results & Analysis
(Highlights)

Total Time In Maze

Control Performs Better Than Egocentric Map
Exocentric (North Up) Map Performs Better Than Egocentric

ANOVA

ANACOVA (Age Covariate)

Treatment (I)	Treatment (J)	Δ (I-J) (seconds)	P
C_M	E_C	-95.8	.035
C_M	E_D	-109.2	.017
C_NM	E_D	-85.0	.064
E_C	X_C	75.8	.094
E_D	X_C	89.3	.050

Percent of Maze Traveled

On Demand Displays Result in Better Performance

Statistics

Treatment	Mean (%)	Std Deviation (%)	N
C_M	93.4	7.4	20
C_NM	96.2	5.2	20
E_C	94.8	5.4	20
E_D	98.2	2.9	20
X_C	93.5	11.9	20
X_D	97.6	5.1	20
Total	95.6	7.0	120

ANOVA

Trtmt (I)	Trtmt (J)	Δ (I-J) (percent)	P-
E_D	C_M	4.8	.030
X_D	C_M	4.2	.057
E_D	X_C	4.7	.035
X_D	X_C	4.0	.067

Ceiling Effect Present. Nevertheless Statistics Relevant for Search Nav.

# Accuracy Scores

(Impact of Small Maze Size)

- Euclidian Directions
  - C_M Better than Exocentric
    - X_C (p=.043)
    - X_D (p=.022)
  - **E_D >X_D (p=.062)**
- Euclidian Distances
  - C_M Better than Exocentric
    - X_C (p=.079)
    - X_D (p=.023)
  - C_M>E_D (p=.004)
  - E_C>E_D (p=.013)
  - **E_C>X_D (p=.064)**

- Cardinal Directions
  - C_M Better than Egocentric
    - X_C (p=.031)
    - X_D (p=.013)
  - E_D > E_C (p=.028)
  - **X_*>E_D**
    - X_C (p=.067)
    - X_D (p=.012)
  - Gender Effects
    - Male>Female (E_C) ANACOVA
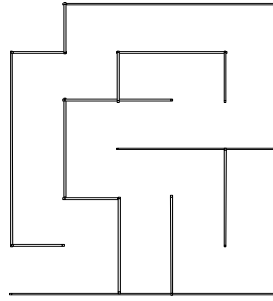   - Suggestive for AR Trtmts
- Spatial Recall
  - No Statistical Significance
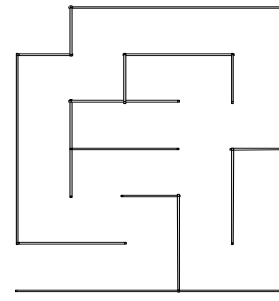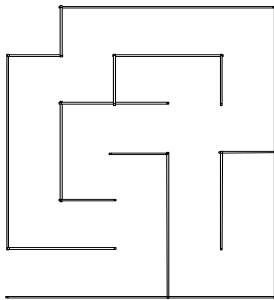
* C and D

Spatial Recall
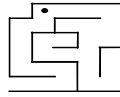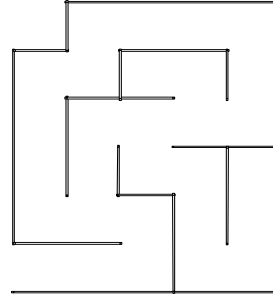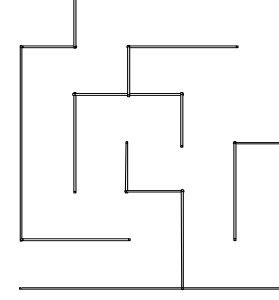

Example
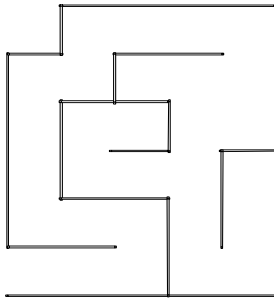
1

2

3

4

5

6

Technical/HF Results

- Improved Ergonomic Design Needed
  - AR Equipment Fit & Ruggedness
  - Tracking, Graphics, & Display Systems
- Improved Interaction Display Controls
  - Hands Free
  - Multi-Modal
- Equipment Training or Intuitiveness
- Customized Design Features on Start Up

Additional Data Analysis (Presence)

- **Many Widely Used Questionnaires**
  - SUS (Slater-Usoh-Steed) PQ
  - Witmer-Singer
    - Immersive Tendencies Questionnaire and Presence Questionnaire
    - Modifications Needed for non-VR
  - ITC-SOPI
    - Cross media

- **Judging Criteria for Questionnaires**
  - Reliability (Repeatable Results Across Trials & Participants)
  - Validity (Correlate with Subjective Measures)
  - Objectivity (Shielded from Bias)
  - Sensitivity (Distinguish Levels/Types of Presence)

University of **Central Florida**

Exploratory Vs Confirmatory Analysis

- **Confirmatory Analysis**
- Inferential Statistics - Deductive Approach
  - Heavy reliance on probability models
  - Look for definite answers to specific questions
  - Emphasis on numerical calculations
  - Hypotheses determined at outset
  - Hypothesis tests and formal confidence interval estimation
- Advantages
  - Provide precise information in the right circumstances
  - Well-established theory and methods
- Disadvantages
  - Misleading impression of precision in less than ideal circumstances
  - Analysis driven by preconceived ideas
  - Difficult to notice unexpected results

- **Exploratory Analysis**
- **Descriptive Statistics - Inductive Approach**
  - Look for flexible ways to examine data without preconceptions
  - Attempt to evaluate validity of assumptions
  - Heavy reliance on graphical displays
  - Let data suggest questions
  - Focus on indications and approximate error magnitudes
- **Advantages**
  - Realistic statements of accuracy
  - Flexible ways to generate hypotheses
  - Does not require more than data can support
- **Disadvantages**
  - Usually does not provide definitive answers
  - Requires judgment

Comparison of results

Subscale	Items	Cronbach Alpha (α)
ITQ:		
FOCUS	1, 3, 8, 9, 19, 21, 34	**0.376**
INVOLVE	2,11,12,17,18,22,23	**0.629**
NEW GEAR	23, 35, 26, 35, 38	**0.466**
PQ:		
INVOLVE / CONTROL	1, 4, 10, 14, 18, 19, 20, 21, 26, 28, 38	**0.622**
INTERFACE QUALITY	22, 23, 24	**0.361**
GEAR	31, 33, 36	**0.376**

Table 1 Subscales for Goldiez questionnaire using Original Witmer-Singer clusters (Blind method)

Subscale	Items	Cronbach Alpha (α)
ITQ:		
PSYCHOMOTOR TENDENCY	6, 8, 10, 11, 15, 30, 35, 36	**0.786**
COGNITIVE INVOLVEMENT	12, 17, 18, 19, 21, 23	**0.733**
PERCEPTUAL INVOLVEMENT	1, 2, 3, 9, 14, 20	**0.675**
PQ:		
HUMAN COMPUTER INTERFACE FACTORS	3, 4, 10, 14, 18, 20, 21, 30	**0.769**
TECHNICAL FACTORS	19, 22, 23, 26, 28	**0.561**
KINESTHETIC/ TACTILE FACTORS	1, 13, 17	**0.500**

Table 2 Subscales for Goldiez questionnaire using Principal component Analysis /Rotation method.
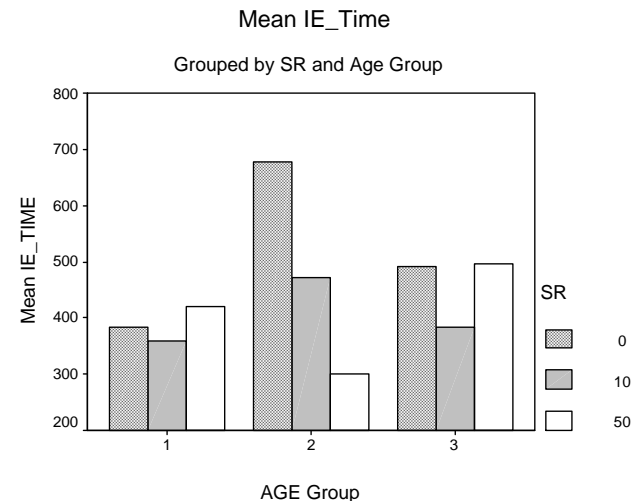
Additional Data Analysis (Demographics)

- **Males Performed Better Than Females**
  - In Both Traversal Time & % Covered (Marginal $p<.10$)
  - Spatial Visualization & Orientation ($p<.01$)

- **Other Results Not Very Conclusive**
  - Various Combinations & Groupings of Other Factors Studied w/o Clear Outcomes
  - Physical Science Majors took 75 s. longer traversal time than aggregate of other majors

- Qualitative Results for Age Group 2 Show Counter Intuitive Relationship Between Recall Accuracy & Time
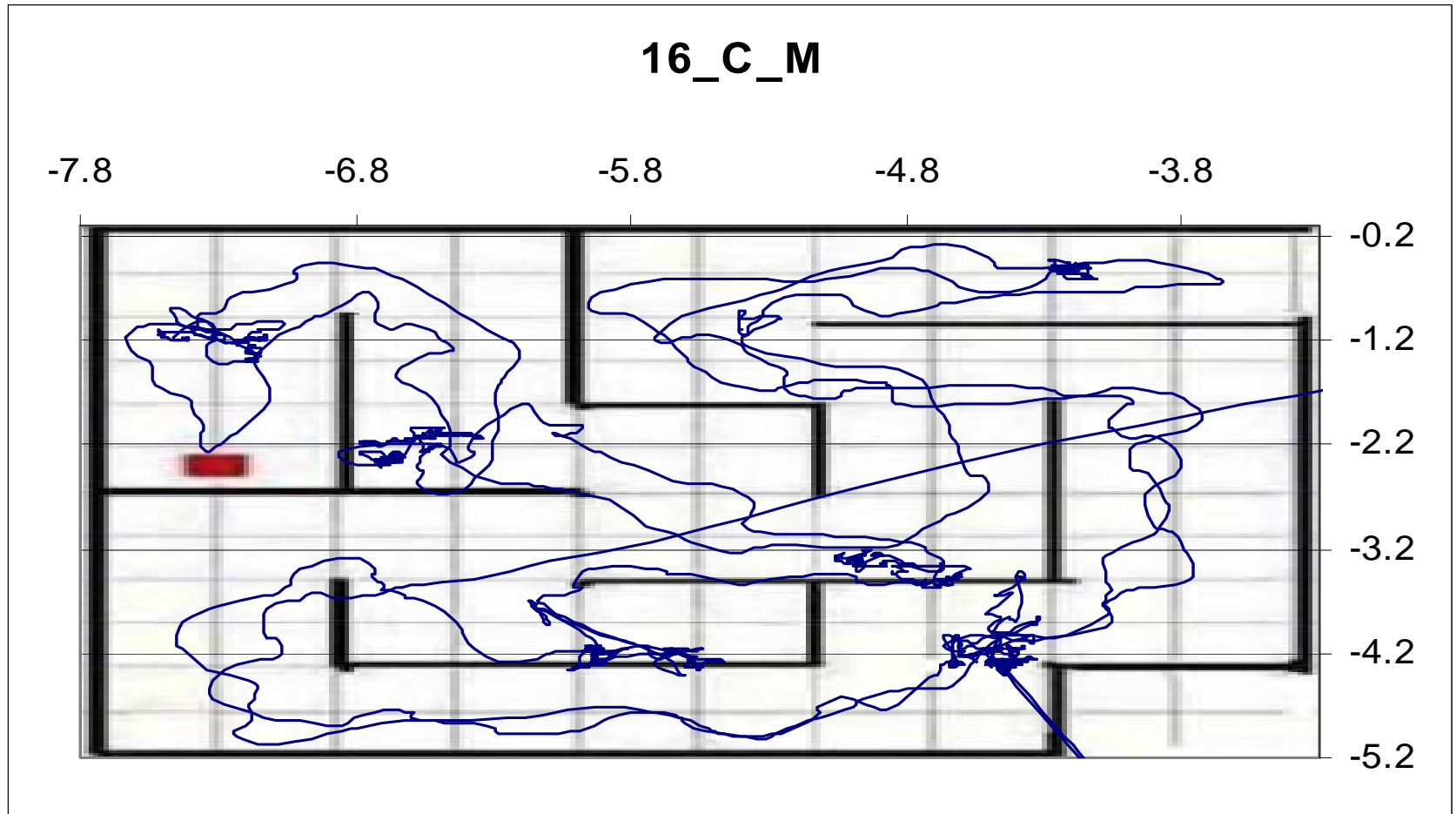
Mean IE_Time

Grouped by SR and Age Group

- Add'l Demographics Study is Indicated

Current Research Activities

- Data Analysis With Respect to Emergent Behavior
  - Determine Relationship (if any) Between Self Motion and Performance
    - Suggest In Situ Remediation/Training Regime
    - Classify User Types

- Additional Presence Research
  - Confirm/Expand ITQ into a Questionnaire Battery
  - Focus Study on ITQ & Expand Across Media
    - Simulator Hardware
    - Robotic Interfaces

- AR Research Roadmap

University of
Central
Florida

Sample of Traversal Trace

16_C_M

Questions?